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Application of Nanoparticles in Cosmetics

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Abstract. The application of nanotechnology in cosmetics can explore the greatest potentials of active substances, leading to improved performance of cosmetics. However, the safety of nanoparticles is still controversial. This review aims to summarize the application and impact of nanotechnology in cosmetics. The advantages and potential drawbacks of nanoparticles in augmenting cosmetic absorption were discussed. A meticulous analysis is conducted to explore how nanomaterials are ingeniously utilized either through their exceptional structural properties or via nanotechnology to magnify the performance of cosmetics. Additionally, the formidable challenges and uncertainties associated with employing nanotechnology in various types of cosmetics were also evaluated.

Keywords: nanomaterial, cosmetics, application, safety.

1. Introduction

Nanotechnology is one of the three great inventions of the 20th century, which addresses nanomaterials who are nuclear aggregates with a size of less than 100 nanometers. Materials at the nanoscale exhibit special properties compared to their bulk counterparts. Nanomaterials, being an essential constituent of materials, have garnered extensive attention due to their exceptional properties in the fields of physics and chemistry.[1]

Among various industries, the cosmetics sector was among the pioneers in embracing nanotechnology materials. For more than 30 years from now, nanoparticles have consistently demonstrated remarkable performance and efficacy within the realm of cosmetics. In the cosmetics industry in EU, nanomaterial is officially defined as insoluble or biologically engineered materials with one or more external or internal nanostructures, ranging in size from one to 100 nm [2]. A diverse range of nanomaterials are currently utilized in cosmetics industry, like nanoemulsions, liposomes, inorganic and organic nanoparticles, dendrimers, nanotubes and nanospheres, as illustrated in **Figure 1**.[3]. Compared to other materials, nanomaterials enhance the stability, color rendering effect, transparency, and makeup holding effect of cosmetics. In addition, they also facilitate efficient transfer of functional components in cosmetics due to their minuscule size [4]. This enhances the UV blocking efficacy of sunscreens, plumping lip lines for a fuller appearance with reinforced antibacterial capabilities.

Amidst the plethora of cosmetics available in the market, this review will specifically expatiate the application of nanoparticles in sunscreens, skincare products, lip makeup, lip care, and cleaning products. In addition, the safety issues related to nano particles were also discussed, and potential improvement strategies were proposed.

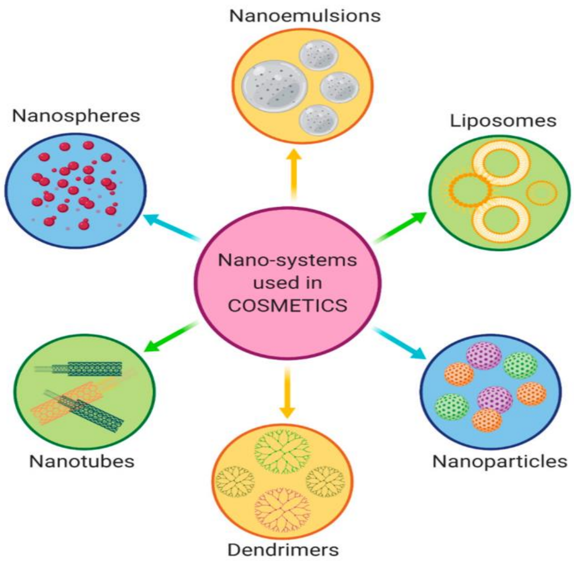

Figure 1. Diverse range of nanomaterials in cosmetics. [3]

2. Application of nanoparticles in cosmetics

2.1. Sunscreen

With excessive sun exposure, the emitted radiation can significantly damage the skin, causing issues like sunburn, photo-aging, melanoma, and non-melanoma skin cancer. Three waves as UVA, UVB and UVC are general categorization of UV radiation in the range of length, with 315-400nm, 280-315nm and 100-280nm respectively. As shown in **Figure 2**., UVA light can penetrate through the dermis and affect both epidermal and dermal layers along with their primary cells. On the other hand, UVB radiation primarily affects the epidermis [**2(A)**]. Prolonged exposure to ultraviolet radiation leads to an amassment of molecules damaged thereby and thus causing hyperpigmentation [**2(B)**], an increased risk of developing cancer [**2(C)**], and premature aging of the skin [**2(D)**][5]. The formulation of sunscreens is constantly evolving due to extensive research on light protection. In this regard, one of the two main inorganic UV filters used in sunscreens: TiO_2 and ZnO will be introduced

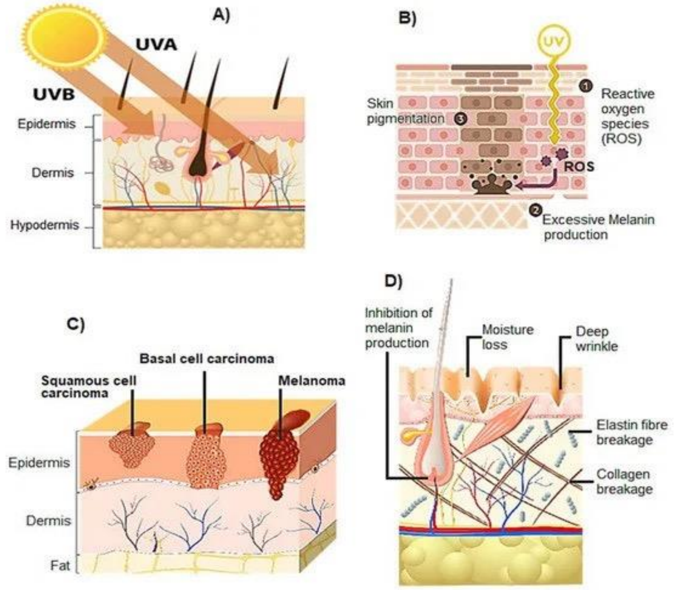

Figure 2. Capacity of UVA and UVB radiation to permeate into skin, and three consequences of exposure to UV radiation repeatedly on the normal skin: (A)in normal condition; (B) excessive pigmentation; (C) generation of cancer; and (D) senility.[5]

2.1.1. TiO_2

Studies have shown that titanium dioxide nanoparticles ranging from 50 to 150 nanometers are optimal for sunscreen formulations. These nanoparticles possess transparency and UV-absorbing properties, making them effective as protective filters [6]. Titanium dioxide (TiO_2) absorbs light within the lengths ranging from 275 to 405nm and simultaneously exhibits high reflectivity due to its elevated refractive factors. By absorbing and blocking rays, TiO_2 effectively prevents rays like ultra-violet A and B from permeating into the skin, providing substantial protection against UV damage. Experimental data has also demonstrated that TiO_2 nanoparticles smaller than 1 micron enhance the sunscreen's protection ability against rays like ultra-violet A and B. Comparative experiments between sunscreen sprays containing metal oxide nanoparticles and those without revealed that titanium dioxide nanoparticles significantly improve the sunscreen's efficacy (**Table 1**) [7].

Table 1. TiO_2 in nano and nornal particle size in Sunscreen and Its protection index. [7]

Product	Usage	Protection index	Components
1	Spray	50 PLUS	nano Titanium dioxide
2	Spray	30	Titanium dioxide

2.1.2. ZnO

The hydrothermal technique was employed for synthesizing ZnO nanoparticles (ZnO NPs), which were characterized using various techniques. The average particle size was determined to be 32.49 nm, with maximum absorbance occurring at wavelengths of 264 nm and 376 nm respectively. Experimental results indicate that ZnO NPs enhance both ultraviolet absorption and transmission. Compared to TiO_2, ZnO demonstrates superior UVB absorption while exhibiting minimal UVA values (**Figure 3**.). Therefore, the UPF value primarily represents protection against UVB rather than broad-spectrum UVA-UVB protection [8].

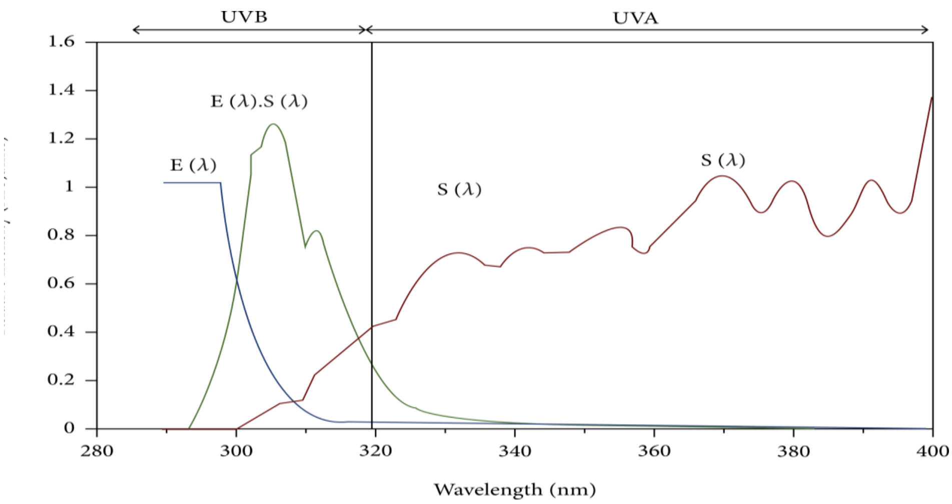

Figure 3. Red thermal spectrum, UVA and UVB, and solar spectrum against radiance.[8]

However, when Titanium dioxide and ZnO nanoparticles mix, a 7% increase in scattering rate with just 5% TiO_2 present occurs. This is because the valence band of TiO_2 can accommodate densely packed electrons, allowing for multiple absorption opportunities when the absorbed energy exceeds the band gap width [9]. Moreover, the introduction of smaller particles (approximately 100nm TiO_2 and approximately 200nm ZnO results in the addition of surface atoms, modification of the band gap width, adjustment of spectral, enhancement in visible light transmission and attainment of particle transparency. This effectively addresses the issue of inadequate opacity.

2.2. Skin care

The incorporation of nanomaterials in cosmetics enhances skin permeability and regulates the liberation of active constituents while improving efficacy for moisturization and staying stable. Additionally, they provide the function of active components for themselves as well. Nano-gold particles (AuNPs) have been utilized in skincare creams, lotions, hair care products, facial masks and other cosmetics for an extensive period of time. [10] Experimental data suggests that the size range of is AuNPs approximately 4nm to 200 nm. Renowned skincare brands employ AuNPs in their cream and lotion formulations to expedite circulation of blood, stimulate cell for reproduction and repair damaged tissues of skin with its anti-inflammatory and anti-corrosive properties. Furthermore, it aids in firming and elasticizing skin while delaying the senility process by promoting the yield of collagen and boosting metabolic vitality, thereby augmenting the effectiveness of skincare products.

Gold peptide nanoparticles, also known as GPNPs (**Figure 4**.). These nanoparticles are composed of nano-sized gold ions and chain polypeptides, forming a more stable spherical structure. This not only ensures the efficacy of the polypeptides but also enhances its ability to penetrate the skin barrier quickly and efficiently, reaching the skin base directly for effective anti-aging benefits. Furthermore, this mechanism can be divided into two parts: antioxidant properties for achieving skin whitening and anti-wrinkle effects for promoting overall skin rejuvenation. The particles effectively inhibit the production of free radicals, thereby reducing oxidative damage to the skin and preserving the functionality of skin cells. Peptides have been found to stimulate metabolism and enhance repair abilities in skin cells while promoting collagen production. Additionally, these particles can boost fiber, collagen, and elastin synthesis while improving neurotransmitter inhibition capabilities. As a result, they help maintain firmness in the skin by preventing sagging or "collapse" issues [11].

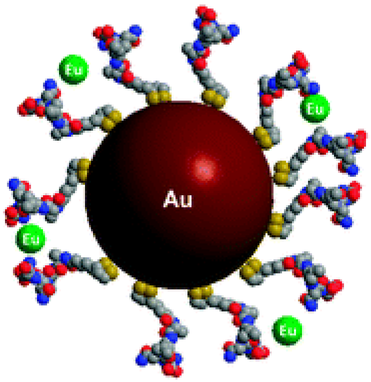

Figure 4. Gold peptide nanoparticles. [11]

2.3. Lipstick and lip balm

Nanotechnology holds the potential to enhance the moisturizing and long-lasting properties, coloration, and lip line filling of lipstick. However, attaining a durable moisturizing function remains challenging with traditional moisturizers due to complex raw material preparation and low yield. Recently, researchers have directed their attention towards carbon dots (CDs) owing to their remarkably small size, unique optical characteristics, and minimal toxicity.[12] The moisturizing effect of CDs is illustrated in **Figure 5**. By subjecting the extracted carmines from cochineal shells to a temperature of 160 ºC and transforming them into CDs in a size of 2.9 nanometers in diameter, these dots form a polymer when combined with water, which can be efficiently absorbed by the skin's surface.

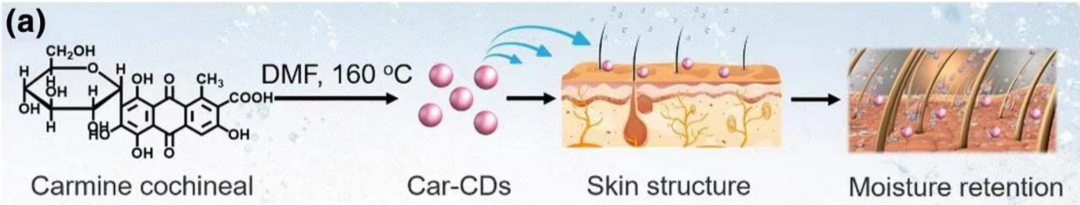

Figure 5. Process of preparing Car - CDs and its capability of staying moisture. [12]

As depicted in **Figure 6a.** and **6b.**, the hygroscopic capacity of CDs exhibited a dose-dependent trend under varying humidity conditions. Figure 6c and 6d demonstrate that CDs retains moisture at rates of 78% and 84%, respectively, within a span of 48 hours at relative humidities of 43% and 81% [13].

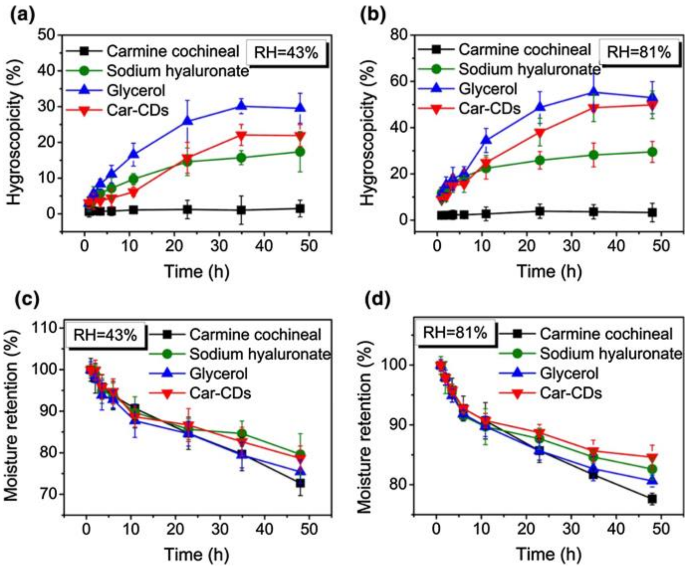

Figure 6. The relationship between wetness, keeping moisture and time at different RH (43 and 81) conditions. [13]

The experiment further investigated the efficacy of CDs for moisturization on skin. As depicted in **Figure 7a**. and **7b**., the moisture levels of participants' hands were measured before and after applying CDs solution, revealing a consistent moisture improvement rate ranging from 27% to 89% over a period of two hours [13].

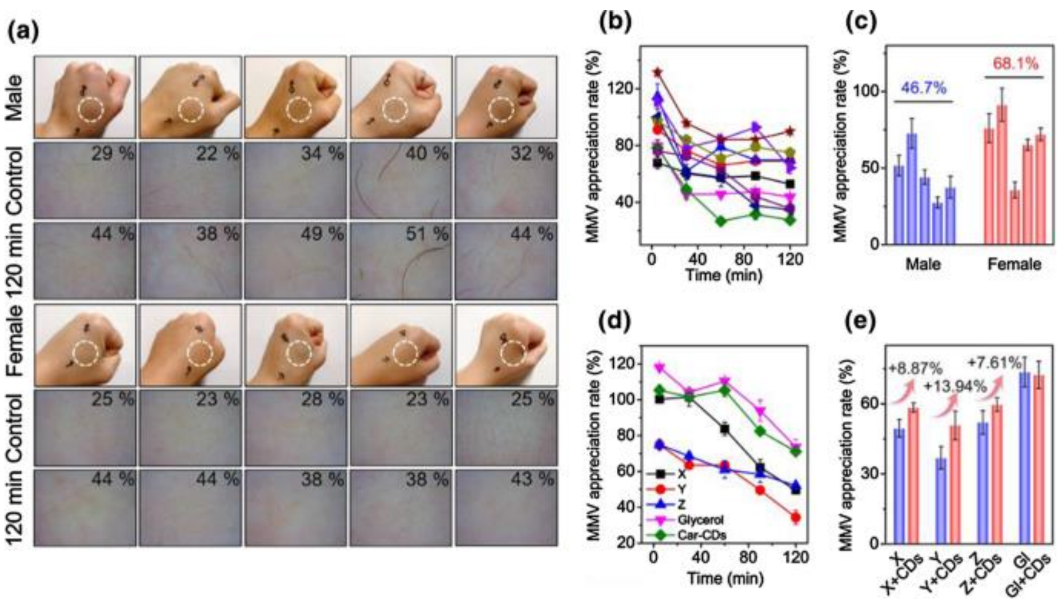

Figure 7. a) Changes of moisture after application of Car - CDs on the volunteers' hand skin. b) Graphs of hand skin moisture content changes. [13]

Additionally, studies indicated that the color shift defect can be mitigated by employing cellulose nanocrystals (CNC) dyes instead of conventional dyes in lipstick substrates. The incorporation of CNC dyes in lipstick effectively suppresses color shift and facilitates easier removal compared to regular lipstick. As depicted in **Figure 8**., this is attributed to the absorption of a portion of the dye by the CNC during the process of color migration, thereby suspending the rate of dyed molecules to spread and thus decreasing color shift possibility [14].

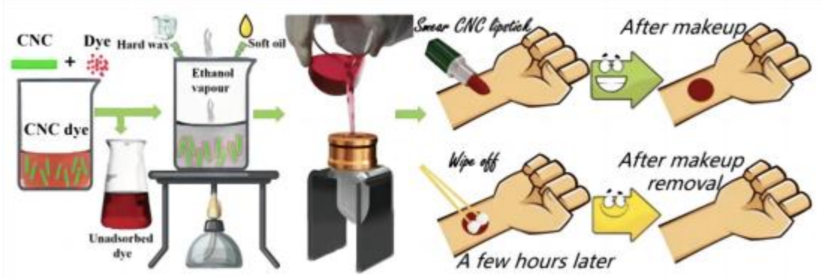

Figure 8. Nanomaterials were employed in the preparation of enhancing lipstick's ability of cleaning color [14].

The utilization of silica NPs, wavelength from 5 to 100 nanometers in size, has demonstrated possibilities to enhance both the visual appeal and even distribution of pigments in lipsticks, while effectively preventing pigment migration into fine lines [3].

3. Security of nanotechnology

Although NPs are widely used in cosmetics, their safety and genotoxicity remain unclear [15]. Each nanomaterial possesses unique characteristics that can provide the desired functions/properties for cosmetics. However, they may also pose risks to consumers. Due to their small size, NPs primarily penetrate the living cortex through hair follicles or intercellular spaces [3]. Several studies have demonstrated that NPs can enter the central nervous system via specific pathways such as receptor-mediated blood-brain barrier endocytosis or endocytosis after adsorption. Given the limited regenerative capacity of the nervous system, lack of effective defense mechanisms, and sensitivity to changes in microenvironments, exposure to NPs is likely to cause irreversible damage. Other possible threats come from skin allergic and photoelectric capacity, which means some NPs can generate electrons by absorbing sunlight. More UV radiation will occur on the skin, which accelerates skin aging. A study by Autier found diseases like melanoma which will threaten life may come from the excessive use of cosmetics formulated without pathogen specifically. [16].

4. Conclusion

In this review, a comprehensive analysis and summary of the application of NPs in cosmetics, as well as the primary existing concerns were conducted. While NPs offer numerous advantages enhancing cosmetic performance, it is undeniable that certain nanomaterials pose potential hazards such as allergies, poisoning, and neurasthenia due to their small size. It is evident that future endeavors should prioritize the discovery of safer, more suitable, and cost-effective nanomaterials. In addition to controlling the particle size of nanoparticles, it is also possible to optimize the formulation of nano-colloids and improve the preparation process of nano-carriers to improve the stability, permeability and effect of the product and provide a better experience for consumers.

References

[1] Mihranyan A, Ferraz N and Strømme M 2012 *Progress in Materials Science* **57** 875-910

[2] Regulation (EC) No 1223/2009, https: //ec.europa.eu/ growth/ sectors/ cosmetics/ products/ nanomaterials_en (accessed on 14 April 2020).

[3] Bilal M and Iqbal H M N 2020 *Cosmetics* *7* 24

[4] Raj S, Jose S, Sumod U S and Sabitha M 2012 *Journal of Pharmacy and Bioallied Sciences* **4** 186-193

[5] Fonseca M, Rehman M, Soares R and Fonte P 2023 *Biomolecules* **13** 493

[6] Tyner K, Wokovich A M, Godar D E, Doub W H, Sadrieh N 2011 *Int. J. Cosmet. Sci.* **33** 234–244

[7] Nandiyanto A, Salsabila D, Aulia F, Hafidza F, Ashfiya P and Salsabila S 2023 *Fullerene Journal Of Chemistry* **7** 1-7

[8] Bulcha B, Tesfaye J L, Anatol D, Shanmugam R, Dwarampudi L P, Nagaprasad N, Bhargavi V L N and Krishnaraj R 2021 *Journal of Nanomaterials* **2021** 8617290

[9] Salvioni L, Morelli L, Ochoa E, Labra M, Fiandra L, Palugan L, Prosperi D and Colombo M 2021 *Advances in Colloid and Interface Science* **293** 102437

[10] Majerič P, Jović Z, Švarc T, Jelen Ž, Horvat A, Koruga D and Rudolf R 2023 *Materials* **16** 3011

[11] Cao M, Li J, Tang J, Chen C and Zhao Y 2016 *Small* **12** 5488-5496.

[12] Dong C, Xu M, Wang S, Ma M, Akakuru O U, Ding H, A Wu, Zha Z, Wang X and Bi H 2021 *Nanobiotechnol* **19** 299

[12] Kang L, Chen P, Wang B, Jia J, Li J, Zeng J, Cheng Z, Gao W, Xu J and Chen K 2020 *Cellulose* **27** 905-913,

[13] Shen Y, Yang Z, Wang T, Wang C, Li L and Chen G 2021 *Spectroscopy and Spectral Analysis* **41** 2665-2669

[14] Yang Y, Wang X, Wen H and Geng X 2019 *Chinese Journal of Pharmaceutical Sciences* **36** 1061-1070

[15] Autier P 2005 *Expert Review of Anti-infective Therapy* **5** 821-33